NASA Science Mission Directorate
Earth Science Division
Applied Sciences Program

Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data

W. Josh Weiss, PhD, PE (Hazen and Sawyer)

NASA Water Resources PI Meeting
April 26-28, 2016

Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data

Our Team:

Hazen

- Project management
- Data collection
- Statistical analysis
- Scripting and algorithm development
- User applications

RIVERSIDE

- Data acquisition systems
- Database development
- Data QA/QC
- Software and web development

UMBC

- RS data acquisition and interpretation
- Existing RS tools
- Statistical analysis
- Landsat modeling

TECHNICAL ADVISORS

- Ben Zaitchik (JHU)
- Dave Reckhow (UMASS)
- Greg Schwarz, Kernell Ries (USGS)

Water Research Foundation℠

- End user engagement
- Outreach
- Dissemination of results

Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data

- **It is well established that watershed processes impact water quality**
- **Monitoring data usually limited to only raw/source water**
- **Direct, frequent measurement is best but can be costly, impractical**
- **Watershed data can provide longer-term outlook**

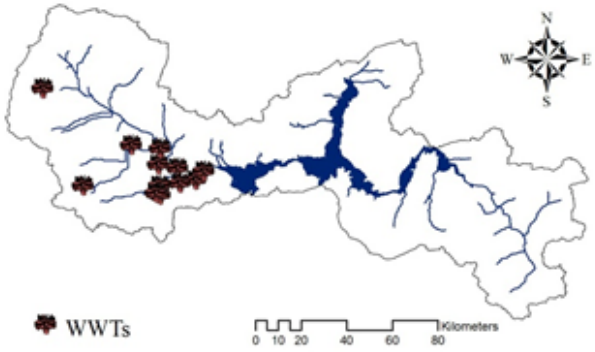
- Seasonal cycles
- Climate/weather
- Extreme events
- Land use changes
- Acute contamination

- Natural organic matter
- Nutrients (N, P)
- Sediment/ turbidity
- Pathogens

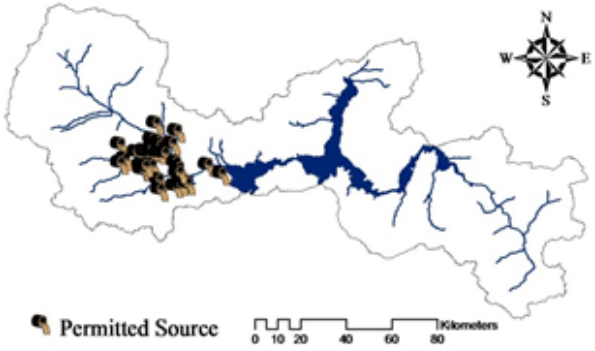
- Increased treatment costs
- Risk to regulatory compliance
- Reduced delivery capacity
- Emergency outages/ boil water alerts

- Increased cost of water
- Water use restrictions
- Public health impacts
- Reduced public confidence in municipal supplies

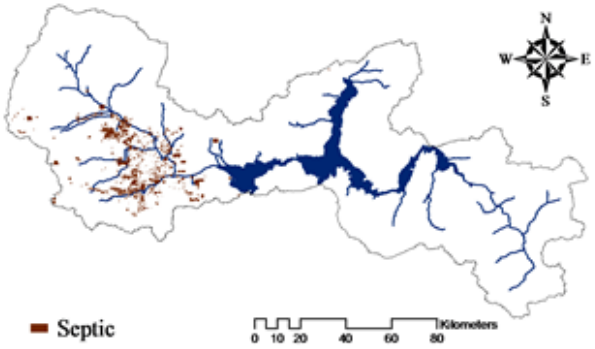
Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data



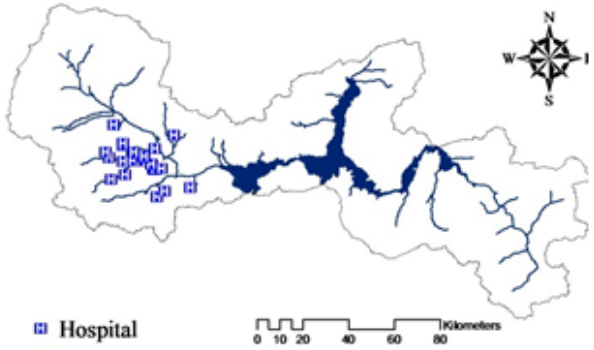
WWTPs



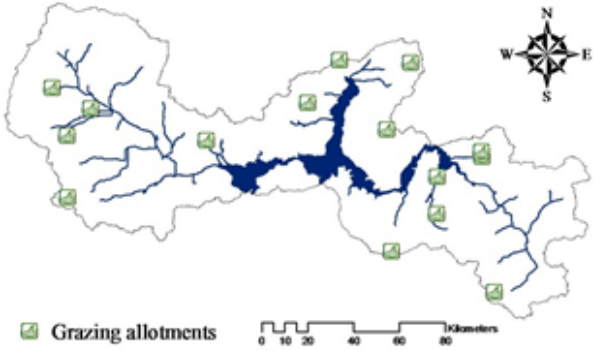
NPDES permitted sources



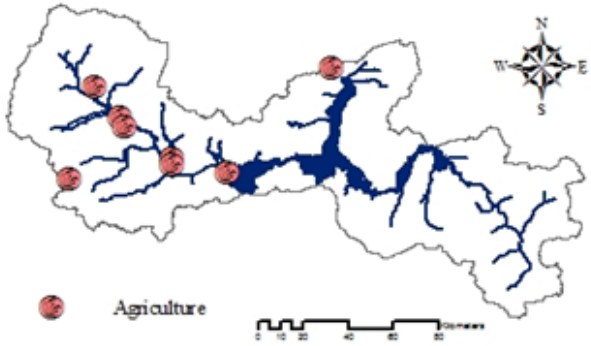
Septic



Hospital



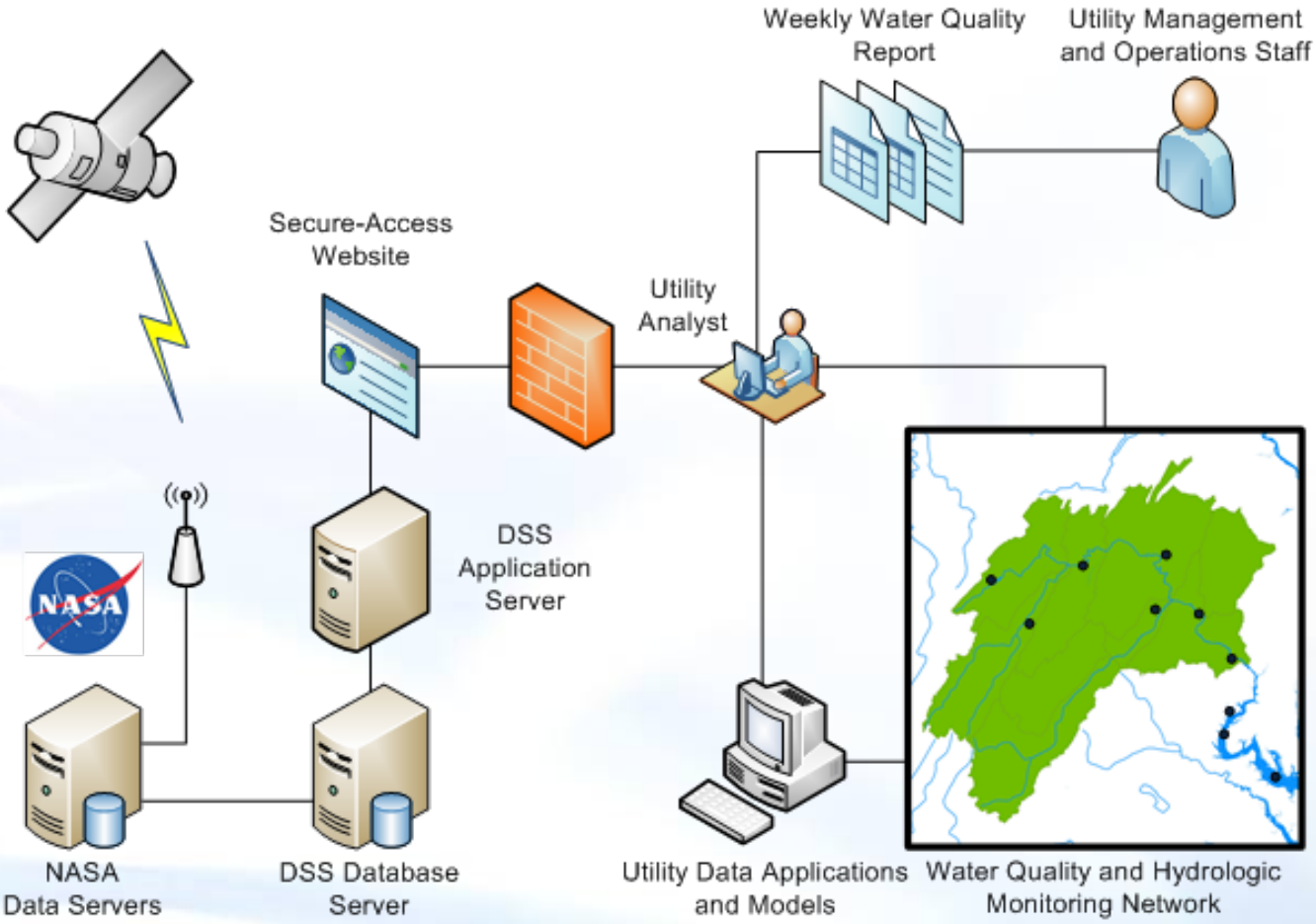
Grazing area



Agriculture

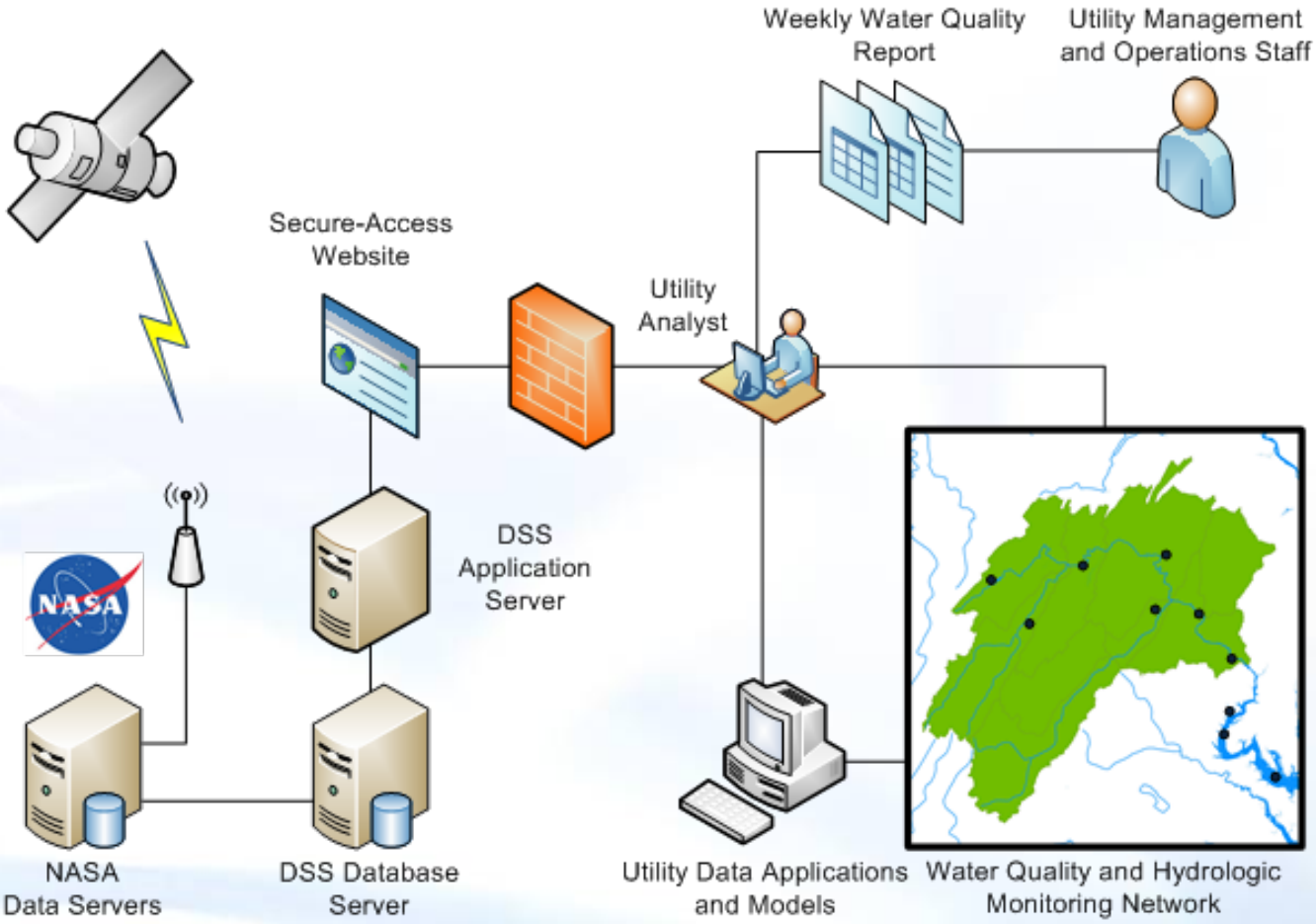
(created by Umass)

Opportunity!



Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data

Opportunity!

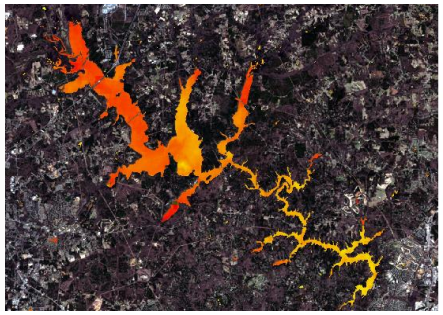


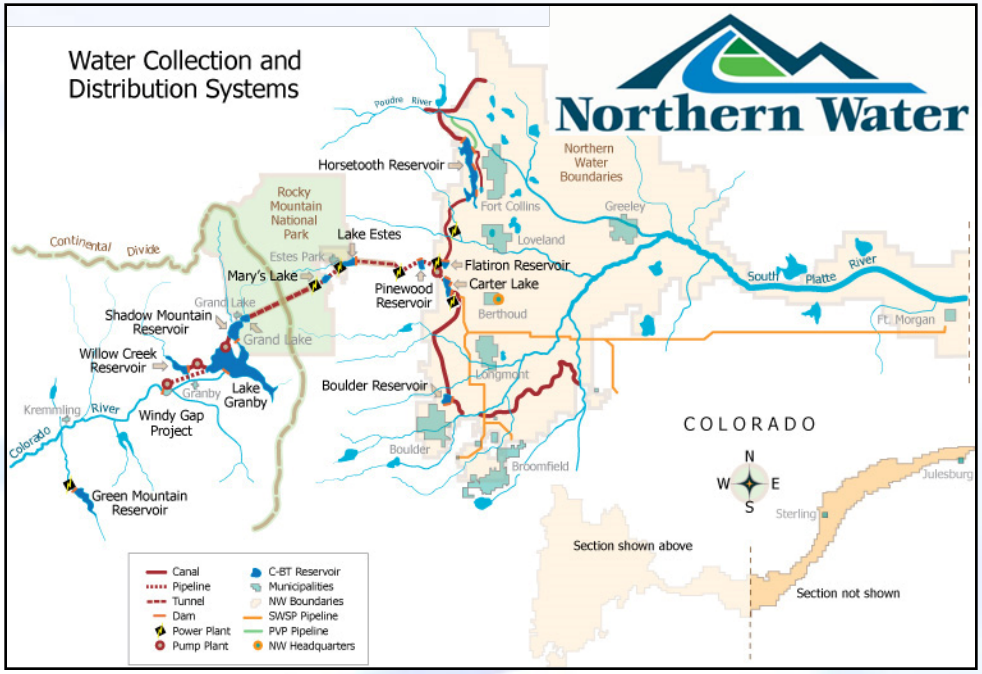
Utility decision-making

- Source selection
- Treatment optimization
- Targeted monitoring
- Identify hotspots
- Long-term tracking
- Detailed modeling
- Proactive mitigation

Current partners and user community

CITY OF RALEIGH NORTH CAROLINA





NYC Environmental Protection

Water Research Foundation℠
advancing the science of water

New York State Energy Research and Development Authority Project: Remote Sensing of Current and Future Vulnerability to Eutrophication and Algal Blooms in New York

NEW YORK STATE OF OPPORTUNITY. NYSERDA

DEPARTMENT OF ENVIRONMENTAL CONSERVATION • NEW YORK STATE •

MOHAWK VALLEY WATER AUTHORITY

OCWA Onondaga County Water Authority

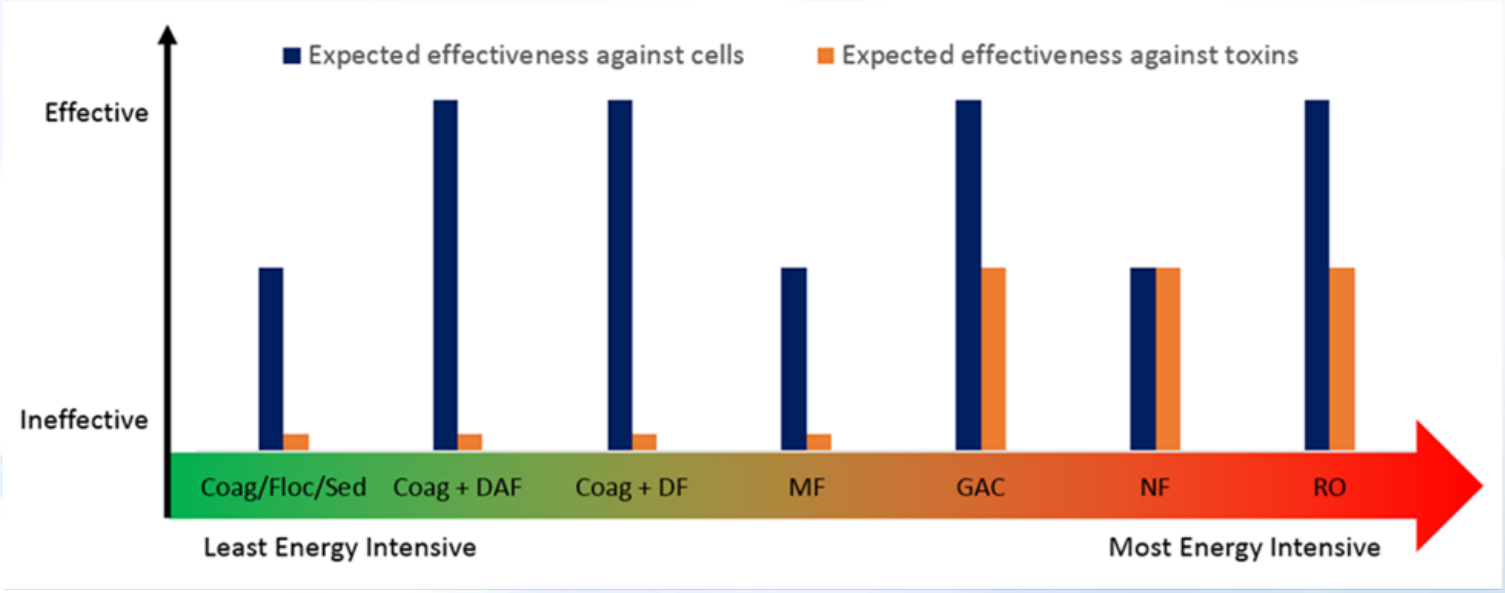


Figure 1: Physicochemical treatment processes and their likely effectiveness at eliminating algae and cyanotoxins of interest in finished water, sorted by energy requirements

We are continuing to reach out to the utility community for additional case studies (more data!):

- **Existing Hazen-utility relationships**
- **Industry conferences (e.g. Texas Water, AWWA Annual Conference)**
- **WaterRF subscribers (future webinar)**
- **Government agencies (USGS, NOAA, state environmental departments)**

Decision Support System to Enhance Source Water Monitoring and Modeling using Remote Sensing Data

In Situ Data:

Utility	Watershed / water body	No. of monitoring sites	No. of WQ parameters	Approx. date range
City of Raleigh	Falls Lake	10	23	1995-2014
NYC DEP	Schoharie Reservoir	7	13	2000-2015
NYC DEP	W. Ashokan Reservoir	7	13	2000-2015
NYC DEP	E. Ashokan Reservoir	5	13	2000-2015
NYC DEP	Pepacton Reservoir	6	13	2000-2015
NYC DEP	Cannonsville Reservoir	6	13	2000-2015
NYC DEP	Neversink Reservoir	5	13	2000-2015
NYC DEP	Rondout Reservoir	7	13	2000-2015
Northern Water	Carter Lake	2	13	1994-2015
Northern Water	Grand Lake	3	13	2000-2015
Northern Water	Horsetooth Reservoir	8	13	1994-2015
Northern Water	Lake Granby	5	13	1995-2015
Northern Water	Shadow Mountain Reservoir	13	13	1995-2015
Northern Water	Willow Creek Reservoir	1	11	2008-2015
Northern Water	Windy Gap Reservoir	1	10	2008-2015

Data Characteristics (Example – DEP Schoharie Reservoir):

var	nAutumnPt	nAutumns	nSpringPts	nSprings	nSummerPts	nSummers	nWinterPts	nWinters	nYears
chla	24	11	42	13	40	12	0	0	13
colr	23	10	41	12	42	11	0	0	12
cond	11	5	17	6	19	6	0	0	6
fcol	30	11	51	12	47	11	0	0	12
fdsc	20	7	37	7	34	7	0	0	7
noxn	10	5	15	5	14	5	0	0	6
phab	31	12	54	13	48	12	0	0	13
talk	5	4	8	4	7	4	0	0	4
tcol	29	11	48	12	46	11	0	0	12
totn	21	10	36	12	35	11	0	0	12
totp	28	12	52	13	47	13	0	0	13
tssd	22	10	36	12	39	12	0	0	12
turb	24	9	42	9	38	9	0	0	10

Data Characteristics (Example – Raleigh Falls Lake):

var	nAutumnPt	nAutumns	nSpringPts	nSprings	nSummerPts	nSummers	nWinterPts	nWinters	nYears
brmd	14	6	12	6	14	6	13	5	6
chla	22	7	27	8	29	8	17	5	8
co2d	1664	20	1589	20	1676	20	1533	19	20
colr	1794	20	1712	20	1778	20	1684	19	20
cond	473	6	379	6	389	6	374	5	6
fcol	549	6	483	6	548	6	451	5	6
hard	1790	20	1623	20	1803	20	1606	19	20
iron	1795	20	1742	20	1826	20	1701	19	20
mang	1838	20	1750	20	1836	20	1691	19	20
nh4n	22	7	27	8	29	8	17	5	8
noxn	22	7	27	8	29	8	17	5	8
phmn	550	6	482	6	548	6	451	5	6
phmx	552	6	485	6	552	6	451	5	6
suva	9	3	9	3	9	3	6	2	3
talk	1840	20	1752	20	1836	20	1746	20	20
tcol	548	6	483	6	548	6	451	5	6
tknn	22	7	27	8	29	8	17	5	8
torc	24	6	29	8	31	8	20	5	8
totn	22	7	27	8	29	8	17	5	8
totp	22	7	27	8	29	8	17	5	8
tssd	22	7	26	8	29	8	17	5	8
turb	1840	20	1812	20	1836	20	1805	20	20
u254	63	6	66	5	60	6	54	5	6

Satellite Watershed-level Data:

Satellite	Sensor	Parameters
TRMM	PR, TMI, TMPA	Rainfall
GPM	DPR,GMI, IMERG	Rainfall, Snowfall
Aqua/Terra	MODIS	Snow Cover
SMAP (Also available from TMI and SSM/I)	Microwave Radar (synthetic aperture) and Radiometer	Soil Moisture
NLDAS (model with satellite data asimillation)	LIS Model	Run Off Soil Moisture Snow Melt
Terra/Aqua/NPP	MODIS/VIIRS	Snow Cover Vegetation Indices, Fire/Burn Area Information
Landsat	ETM+, OLI	Land cover
Space Shuttle	SRTM /DEM	Terrain

Satellite Watershed-level Data:

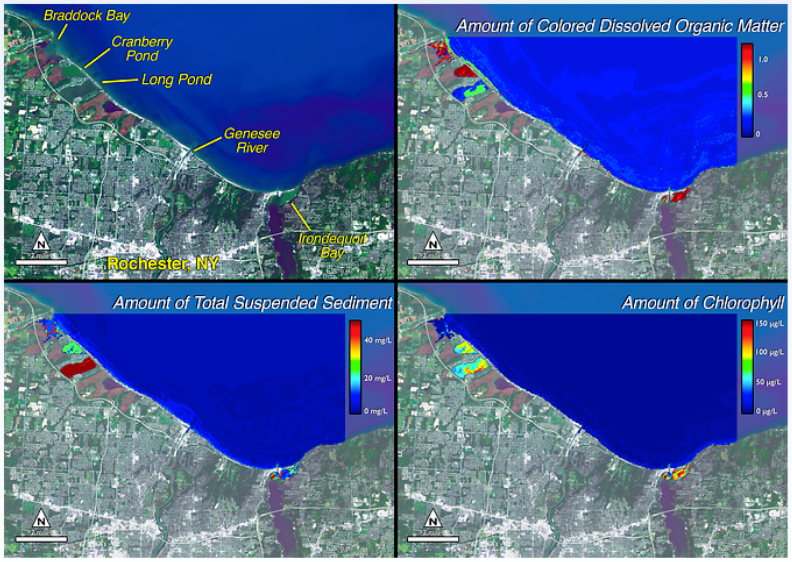
MODIS Name	Product Name Short name	Spatial Resolution (m)	Temporal
MOD 09	Surface Reflectance	500	8-day
MOD 11	Land Surface Temperature	1000	Daily, 8-day
MOD 12	Land Cover/Change	500	8-day, Yearly
MOD 13	Vegetation Indices	250-1000	16 day, monthly
MOD 14	Thermal Anomalies/Fire	1000	Daily, 8-day
MOD 15	Leaf Area Index/Fraction of Absorbed Photosynthetically Active Radiation (FPAR)	1000	4-day, 8-day
MOD 16	Evapotranspiration		
MOD 17	Primary Production	1000	8-day, yearly
MOD 43	Bidirectional reflectance distribution function (BRDF)/Albedo	500-1000	16-day
MOD 44	Vegetation Continuous Fields	250	yearly
MOD 45	Burned Area	500	monthly

- **All MODIS Land Products are available at processing Level 3**

Satellite Watershed-level Data:

- Spectral reflectance and imagery available on-line, numerous studies use these information to get the following parameters over various locations:

  Chlorophyll Concentration, Secchi Disk Depth, Suspended Particles, Turbidity, Colored Dissolved Organic Matter



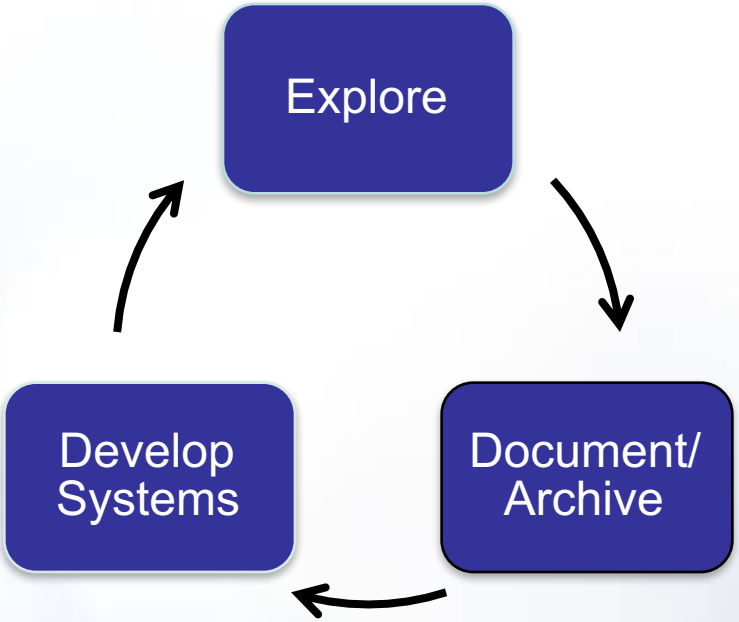
Landsat 8's new blue band and improved ability to distinguish subtle color variations help researchers study coastal water quality. John

Landsat 8's new blue band and improved ability to distinguish subtle color variations help researchers study coastal water quality. Image Credit: RIT/NASA/USGS

http://www.nasa.gov/content/goddard/taking-nasa-usgs-s-landsat-8-to-the-beach/#.VG64blfUmlg

Data Analysis and Script Development

- **Explore**
  - Download data
  - Initial data analysis
    - Spatial/temporal aggregation
    - Transformations/derivatives of raw data
    - Correlation/regression analysis with WQ data
- **Document/Archive**
  - Document usefulness
    - What datasets, derivatives are good predictors?
    - Share algorithms/scripts
- **Develop systems**
  - Strategies/scripts/tools for automated data acquisition and processing



Statistics

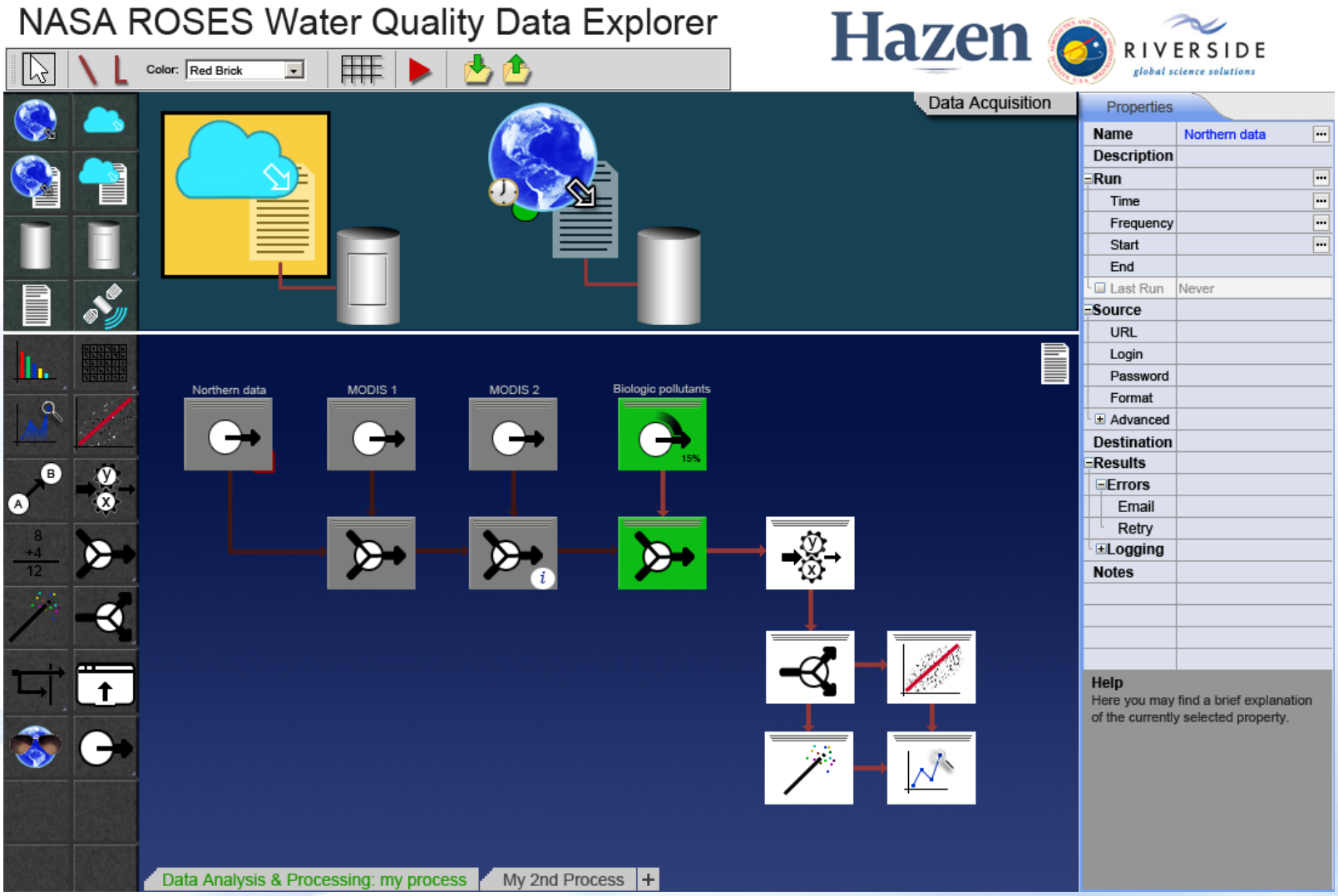
- Correlation testing
- Linear regressions – simple and multiple
- Weighted Regressions (WRTDS)
- Partial Least Squares (PLS) analysis
- Principal Component Analysis (PCA)
- Logistic regressions for probabilistic risk predictions

Software Development

Requirements Report

- Set the Stage
- Understand the Target Audience
- Capture Business Requirements
- Capture Functional Requirements
- Best Industry Practices:
  - Living Document
  - Iterative
  - Easily Available for Review and Comments

Software Development (cont)



Anticipated Impacts:

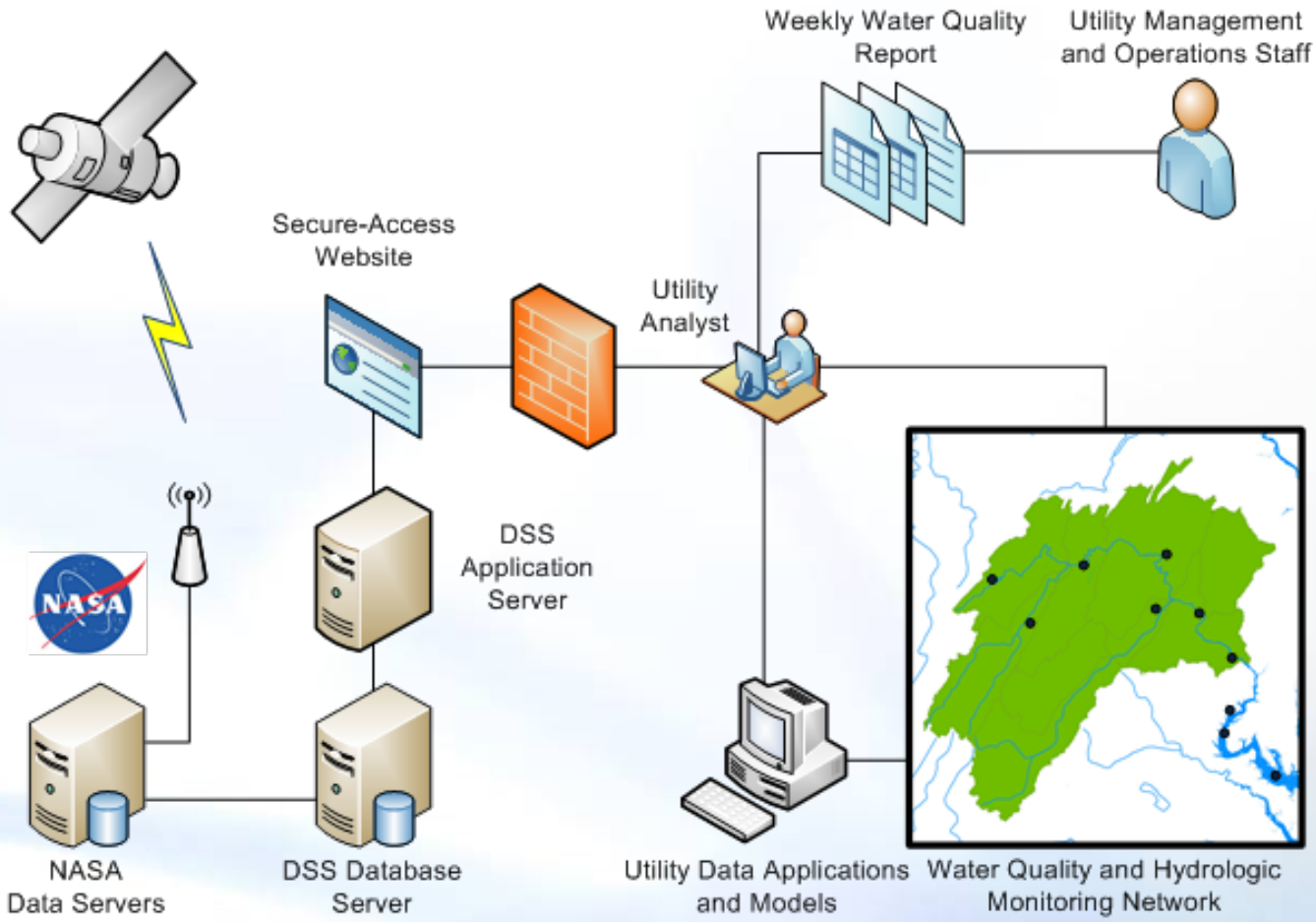
Near-term water resources management

- Source selection
- Treatment process optimization
- Improved monitoring resolution
- Stakeholder notification support

Long-term water resources planning

- Climate change vulnerability assessment
- Watershed management
- Project prioritization

Transition Strategy TBD

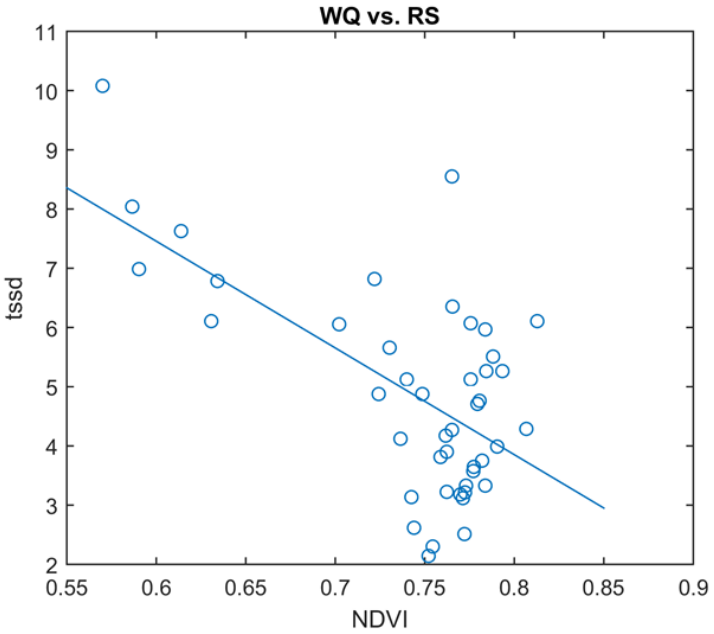


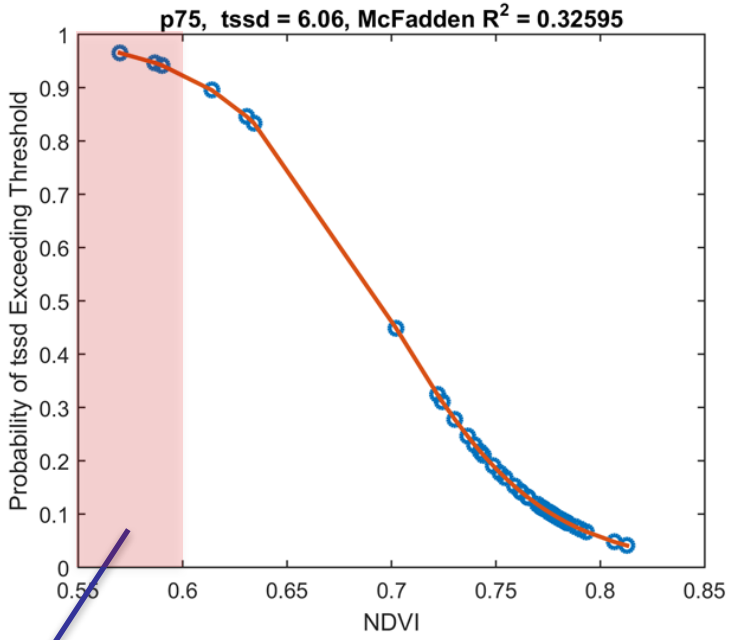
Lessons Learned / Challenges

- Limited in situ data
  - We're exploring alternative aggregations, e.g. statistics across watershed while controlling for climate, land use, etc.

Examples

- Hypothesis: Higher NDVI for the current season (no lag) means more vegetation and less overland runoff to deliver solids to the reservoir





For values of NDVI equal to or less than 0.6, there is a ~90% chance of TSS exceeding 6 mg/L

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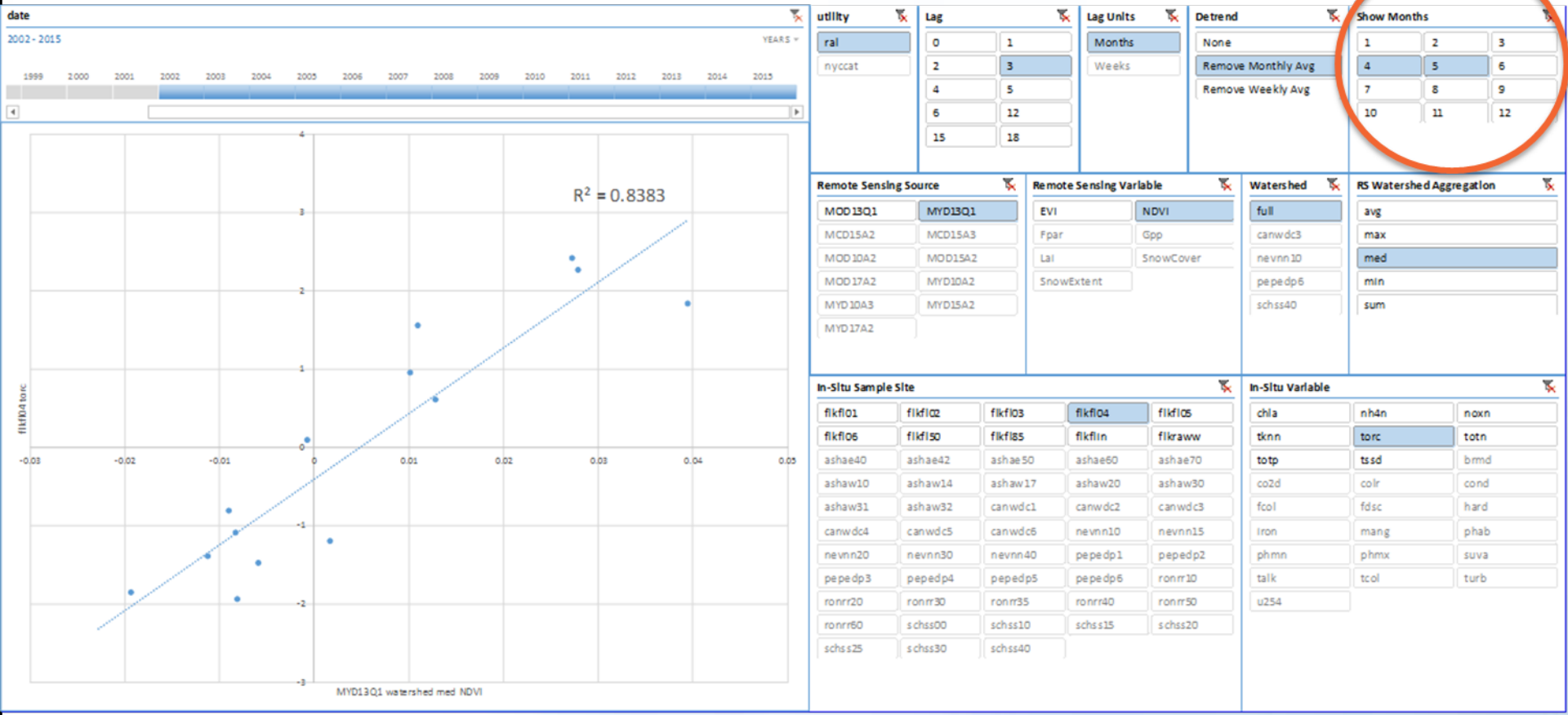
Examples

Exploratory Data Dashboard



MODIS Watershed NDVI (lagged 3 months) and In Situ Reservoir Total Organic Carbon Scatter

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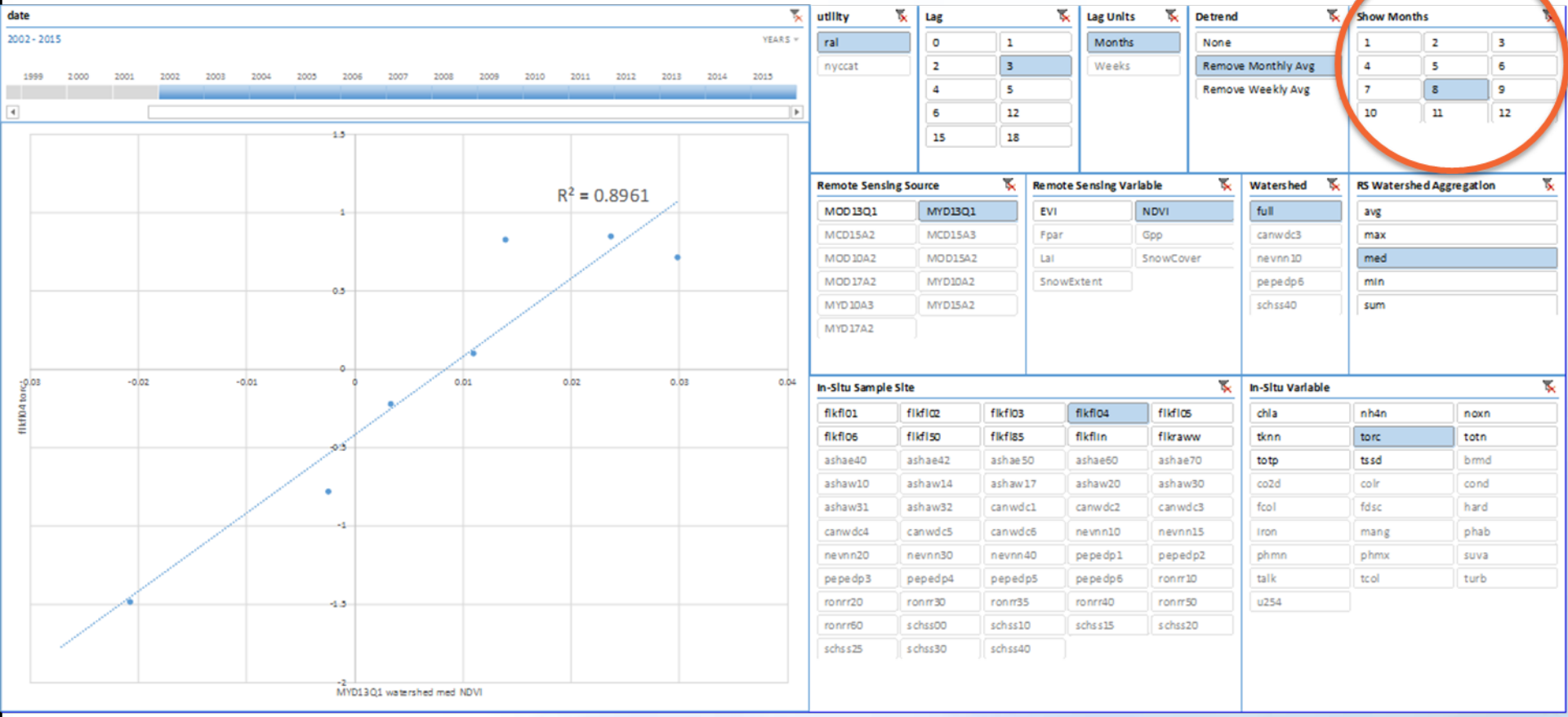
Examples

Exploratory Data Dashboard



MODIS Watershed NDVI (lagged 3 months) and In Situ Reservoir Total Organic Carbon Scatter

Papers

Current focus is marketing within the water utility and agency communities

- Texas Water (April)
- National Water Monitoring Conference (May)
- Data Flow 2016 (LSU, May)
- AWWA Annual Conference (June)